

Potential of Controlled Environment Agriculture in a Super-Aging Society

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1 Introduction

Japanese society has been aging at an unprecedentedly rapid pace, and the percentage of those aged 65 or over is expected to reach around 40% of the total population in 2050. Due to extended life expectancy, people have come to have a longer post-retirement life. In a society where the productive-age population ratio declines in line with an increasing aging population, new employment opportunities need to be prepared for the elderly who are willing to work so that they can continue to work, depending on their physical strength, even after retirement.^[1] As the aging population is supposed to increase significantly in metropolitan areas in particular, environmental arrangements for a super-aging society are required both in urban areas and local areas.

Results of surveys on elderly people's life trends show that agriculture and gardening is one of the popular pastimes for the elderly. Furthermore, it is widely known that agricultural work and gardening have good effects on people's mental and physical health, and they are expected to help improve the quality of life. If new employment opportunities for the elderly can be prepared based on such features of agriculture and gardening, this will be a new city model for a super-aging society.

In recent years, with growing environmental awareness and inclination toward an enriched lifestyle, more and more people in cities have come to enjoy the casual cultivation of plants and vegetables in rooftop gardens. In the United States, a new style of agriculture is being introduced at rooftop hydroponic facilities, where plants and vegetables can be grown stably throughout the year. Bearing such new trends in mind, this report discusses the potential of controlled environment agriculture in urban areas in a super-aging society and explains recent studies on plant

factories, which may hold the key to realize this new style of agriculture.

2 Social Background of the Employment of the Elderly

2-1 Population aging will accelerate, especially in urban areas

Japan's total population peaked at 127.84 million in 2004 and has been in a long-term declining trend. It is estimated that the total population will decrease by nearly 26% to 95.15 million by 2050. During this period, the elderly population aged over 65 will increase by nearly 12 million, while the productive-age population aged between 15 and 64 will decrease by nearly 35 million. As a result, the population aging rate is estimated to increase from nearly 20% to 40%. The population will be sparse in most parts of the nation, while concentrated in some areas, such as the Tokyo and Nagoya metropolitan areas.^[2,3] The increase rate of the elderly population will be high in the Tokyo, Nagoya, and other metropolitan areas during the period from 2005 to 2035 (Figure 1). Looking at the changes in the elderly population by prefecture, some prefectures start to show decreases in and after 2020. As of the year 2035, prefectures that hold a large number of elderly people will be those with big cities, such as Tokyo, Kanagawa, Osaka, Saitama, and Aichi.^[2,4] Based on these data, it is clear that population aging will progress nationwide and demographic composition will change drastically, particularly in big cities. Therefore, it is necessary to develop an environment that can respond to the coming super-aging society in urban areas, including big cities.

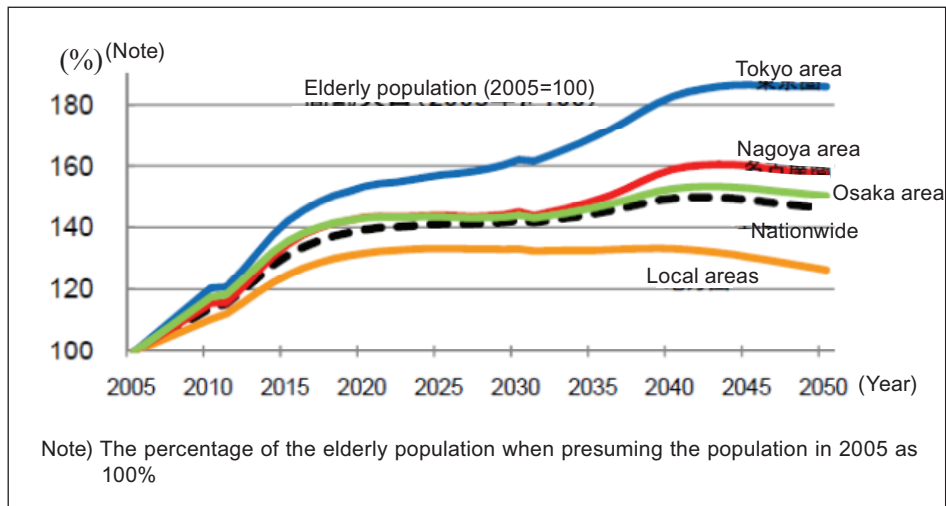


Figure 1 : Changes in Elderly Population by Urban Area
Source: Reference^[2] with data partially added by the STFC

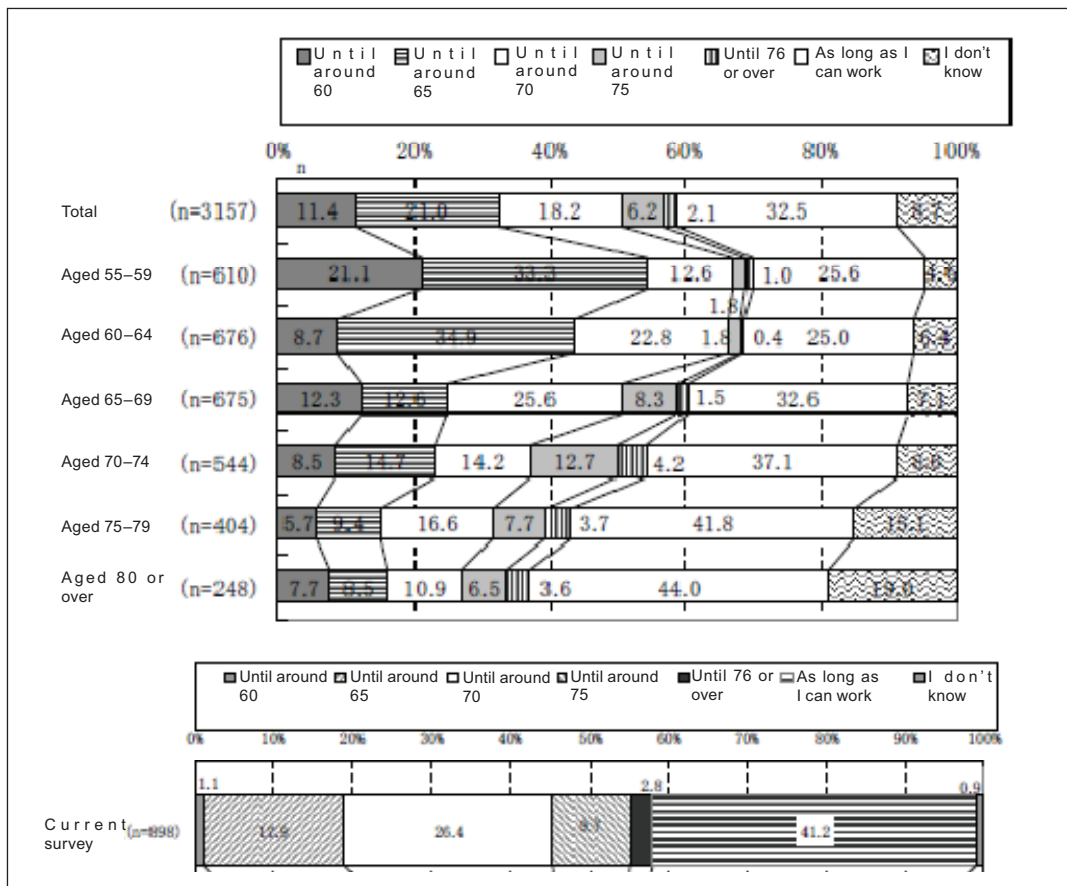


Figure 2 : Until What Age do You Want to Work?
Source: Extracted from Reference^[5]

2-2 The quality of post-retirement life needs to be enhanced

The average life expectancy in 2008 was 79.29 for men and 86.05 for women, and may increase to 83.67 for men and 90.34 for women by 2055.^[3] Life after retirement may lengthen to 20 to 30 years and the elderly need to consider how to spend this period of time and design their lives depending on their personal lifestyle.

Health conditions change with age, but many people

want to work for the purpose of seeking satisfaction in life. The survey conducted by the Cabinet Office in 2007 shows that nearly 80% of the elderly aged 60 or over want to work until they become 70 years old^[5] (Figure 2). In an aging society where the productive-age population decreases, new employment opportunities need to be prepared for the elderly who are willing to work so that they can continue to work, depending on their physical strength, and can maintain contact with local communities.

In the next Chapter, I will consider ideal workplaces for the elderly that respond to future changes in society, based on their lifestyle. I mainly cited data for the Tokyo metropolitan area, but the trend can be applied to other urban areas as well.

3 Meaning of Gardening in Elderly People's Lifestyles

3-1 Many elderly people enjoy gardening

Based on the results of the survey conducted by the Ministry of Internal Affairs and Communications in

2006 concerning people's lives from the view point of leisure activities, among people aged 65 or over, the most popular hobby and entertainment was "growing plants and flowers, and gardening" (37.2% for men and 38.7% for women).^[6]

According to the Internet survey conducted by the Tokyo metropolitan government in 2009, 84.6% of Tokyo citizens responded that agriculture and farmland need to be preserved in Tokyo and showed high interest in local agriculture. The major reasons for such response include the significance of agriculture in providing fresh and safe farm products

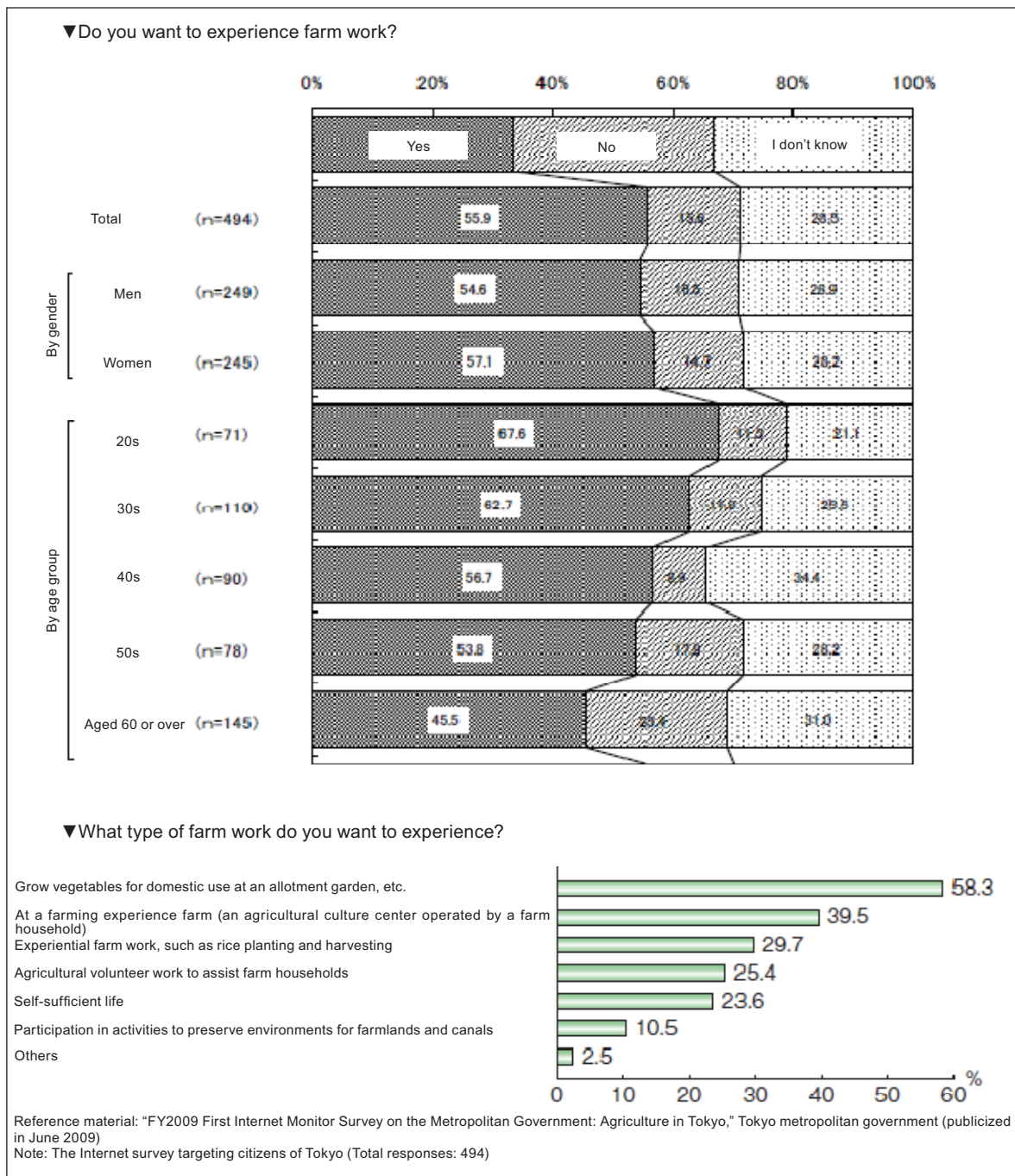


Figure 3 : Awareness Survey "Agriculture in Tokyo"

Source: Reference^[7]

and animal products, and in preserving nature and the environment, as well as its educational function for providing dietary education. Those who want to experience farm work accounted for 56% of the overall respondents, showing high percentages widely among various age groups from 68% for those in their twenties to 46% for those aged 60 or over. Out of such respondents, those who want to grow vegetables at an allotment garden, etc. accounted for the highest percentage, at 58%^[7] (Figure 3).

The number of allotment gardens has been increasing year by year nationwide. They are generally very popular as some have applicants on waiting lists, and the rate of applications is especially high in metropolitan areas^[8] (Figure 4). According to the results of the survey conducted by the Kanto Regional Agricultural Administration Office of the Ministry of Agriculture, Forestry and Fisheries, targeting allotment gardens within its jurisdiction, 70% or more of the users are aged 60 or over^[9] (Figure 5).

From these data, it can be said that gardening is one of the popular activity fields among the elderly and that a higher rate of the elderly in the Tokyo metropolitan area are actually enjoying cultivating vegetables, fruits and flowers in allotment gardens, etc. compared with those in other age groups.

3-2 Gardening are good for mental and physical health

In the fields of horticultural therapy and horticultural well-being, it is widely known that gardening activities help people enhance and maintain their physical functions through moderate exercise, and also has a good influence on their mind by having them feel nature with their five senses (touching soil, growing plants, enjoying greenery, tasting the harvest, etc.). Furthermore, through growing plants, people can have smoother conversation and can share harvests, which helps them build better human relationships and formulate communities.

Scientific analyses have also been conducted concerning these effects of gardening on people's health. For example, a medical epidemiological study has proved that gardening activities have positive influences on the health of elderly men in particular. A follow-up survey was conducted, targeting a total of 9,720 elderly people aged 65 or over who resided in five communities in Aichi prefecture and had not been certified as being in need of long-term care, regarding whether or not they develop dementia in the following three years, in relation to the types of their leisure activities. The results indicate that the risk of developing dementia nearly doubles for elderly men who do not enjoy gardening or growing plants, compared with their counterparts who enjoy such activities^[10] (Figure 6). Gardening, which are highly accessible for the elderly, are expected to help enhance the quality of elderly people's lives after retirement.

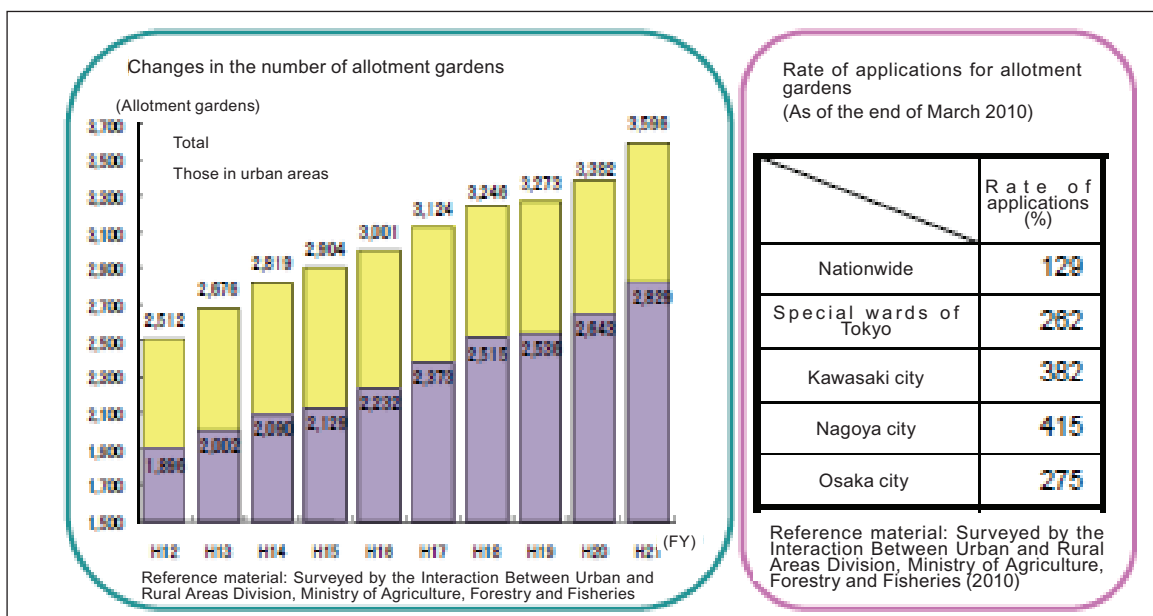


Figure 4 : Changes in the Number of Allotment Gardens and Rate of Applications

Source: Reference^[8]

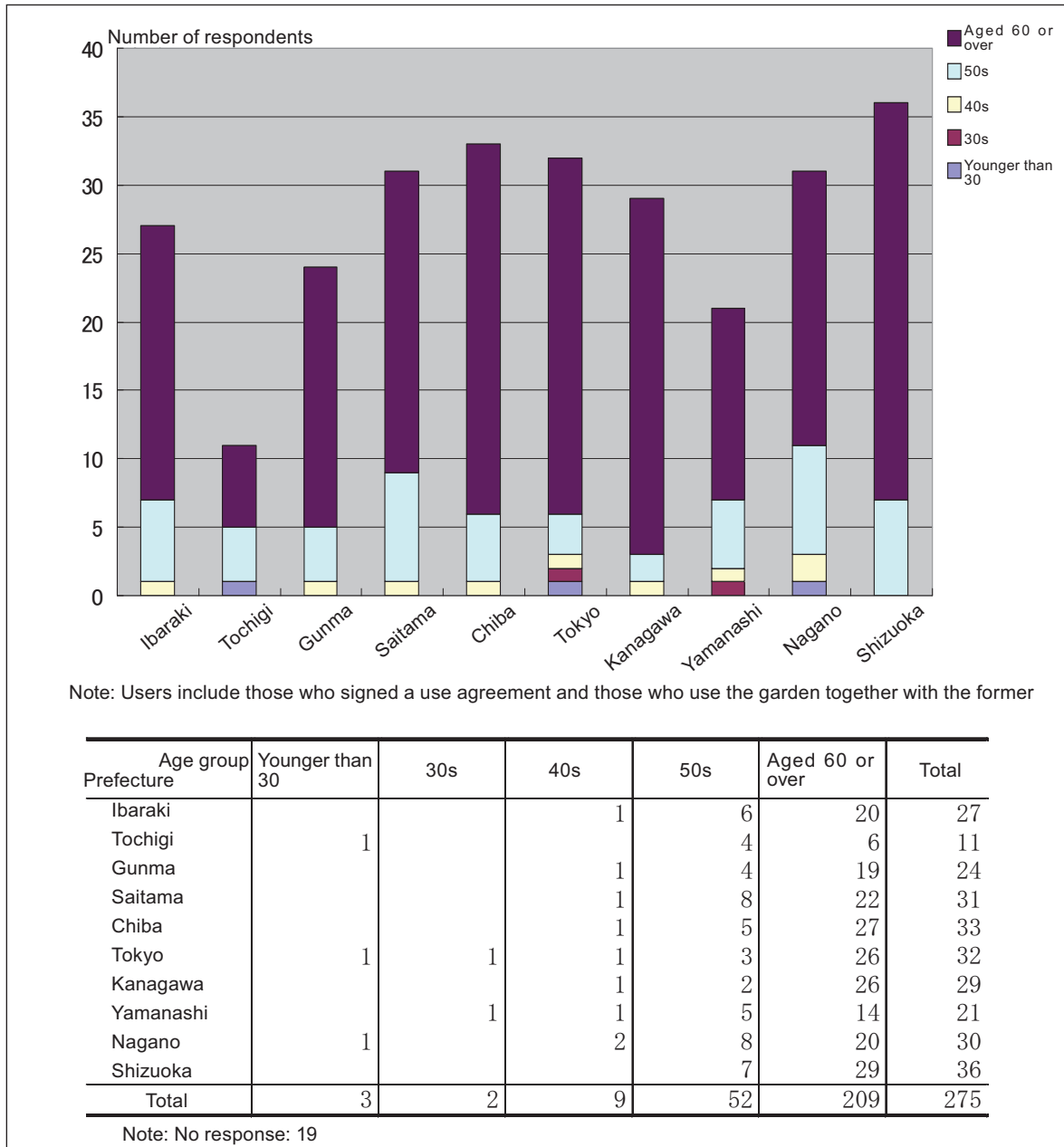


Figure 5 : Number of Users of Allotment gardens by Age Group

Source: Reference^[9]

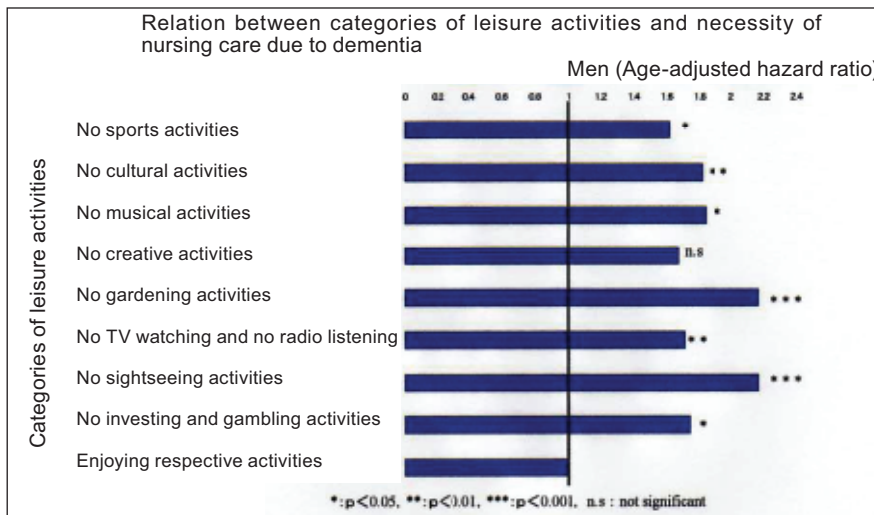


Figure 6 : Types of Leisure Activities and the Risk of Dementia (Men aged 65 or over)

Source: Reference^[10]

4 Considering Employment Opportunities in Agriculture in Urban Areas

4-1 Rooftop gardening facilities have been increasing in urban areas

In recent years, from the viewpoint of reducing heat-island effects and seeking a qualitatively rich living environment, symbiosis with nature has come to be emphasized in planning and designing urban cities.^[11] Under assistance systems by the national and various local governments, the total area of rooftop gardens has been increasing year by year. In 2009, nearly half of the total was in Tokyo, followed by Kanagawa, Aichi, Saitama, and Osaka. Rooftop gardens have thus increased, particularly in metropolitan areas.^[12]

Backed by growing environmental awareness in urban areas, businesses that lend rooftop gardens on buildings have been prevailing in various parts in Tokyo, Takasaki city in Gunma, and Toda city in Saitama, as well as in Nagoya city and Osaka city. A survey conducted by the Ministry of the Environment for collecting examples of space greening showed that people now have larger opportunities to enjoy gardening in city life, with applications often in excess of capacity being made for rooftop gardens by people in a wide age range, from those in their 20s to those in their 70s.^[13] People can enjoy casual gardening in rooftop gardens with less expertise and knowledge required, compared with farm work in allotment gardens. Rooftop gardens are usually located in accessible places, saving users the trouble of traveling, and utilities, such as water and electricity, as well as bathrooms, rest areas and other facilities are available nearby, as functions necessary for daily life are located intensively in urban areas.

4-2 Controlled environment agriculture is being commercialized on rooftops in urban areas in North America

In the U.S., agriculture in cities has attracted people's attention, with growing social needs for securing food safety, promoting local production for local consumption, guaranteeing food security, developing sustainable urban life, and creating jobs, etc. In February 2010, Brooklyn Borough compiled recommendations on a sustainable food system for New York City, in which rooftop agriculture was

proposed.^[14] Open-system agriculture by laying lightweight soil on rooftops was firstly promoted,^[15] but greenhouse hydroponic cultivation is now being introduced. In Brooklyn Borough, a 15,000 square-foot (1400m²) rooftop greenhouse is under construction and the first harvest is expected in June 2011. Eighty tons of vegetables and herbs are planned to be grown annually and be directly sold to local retailers and restaurants.^[16] In Montreal in Canada, rooftop agriculture is going to start with further advanced control over the cultivation environment. In a 31,000 square-foot (2900m²) facility, hydroponic cultivation and solid medium cultivation are carried out depending on crop types. Nutrients, water, light intensity, and temperature are controlled, and crops are cultivated all year round without the use of pesticides. Customer members have already been gathered locally and the first delivery is scheduled for April 2011.^[17]

This type of agriculture, which enables stable year-round production by controlling the cultivation environment optimal to the growth of crops, is referred to as "controlled environment agriculture" in this report. Environmental elements necessary for the cultivation of crops are mainly light intensity, water, carbon dioxide levels, nutrients, temperature, humidity, and countermeasures against disease and pests, but if only stable production is ensured all year round, not all of these elements need to be controlled. In the case of Montreal, which is located in a high-latitude region, measures for summer heat are not necessary. They do not seem to control carbon dioxide levels, either, but this may be based on the consideration of ideal control levels by taking into account the business forms and production costs. Although the sustainability of the business needs to be assessed later, controlled environment agriculture in cities has thus become commercialized in North America.

4-3 Characteristics of controlled environment facilities as workplaces for the elderly

Elderly people's physical strength and health conditions vary by individual, and some healthy people may enjoy outdoor exercises in nature and prefer a farming environment where they can enjoy growing crops in spite of feeling some inconvenience. On the other hand, others may find it difficult to squat down to weed on hot summer days or may prefer to

do farm work indoors during the rainy season or on windy days. In controlled environment facilities, the temperature is usually maintained at around 22 to 25 degrees centigrade throughout the year, providing a comfortable working environment for workers. The workload is also relatively light. From the viewpoint of creating new communities where life in cities and life in rural areas can coexist, Mr. Masayuki Yamamoto, the writer of “Agri-Renaissance,”^[18] states his opinion on controlled environment facilities as follows.

“In urban areas, for example, greenhouses for hydroponic cultivation can be constructed on rooftops of high-rise condominium buildings, schools, and public facilities. Hydroponic cultivation is a type of water-saving farming method, circulating a nutrient solution, and crops can be grown anywhere without soil if only there is sunshine, water, and electricity. Furthermore, being free from bad weather and low temperatures, it is very friendly to the elderly and children. As the environment is controlled by computer, and pesticides to avoid disease and pests are scarcely needed, nice and safe crops can be grown stably. Such farm work is most suitable for the elderly to maintain their good health and look for satisfaction in life... (the rest omitted)”

In controlled environment facilities, workers can engage in farm work in accordance with their physical strength, which may widen the range of the elderly who can obtain employment. As will be explained later in 5-1, controlled environment facilities are included in the category of plant factories. In the next Chapter, I will further consider the potential of controlled environment agriculture in cities for the purpose of providing employment opportunities for the elderly, based on the trends in studies on plant factories.

5 Trends in Studies on Controlled Environment Agriculture

5-1 Trends in High-Tech Greenhouses

In recent years, high-tech greenhouses have come to attract people’s attention again, due to incidents of foreign matter contamination of food, declines in food self-sufficiency ratios, and the upsurge of vegetable prices caused by bad weather. High-tech greenhouses are specific facilities that cultivate plants by controlling the growing environment (such as light, temperature, humidity, carbon dioxide levels, nutrients, and water),

where year-round planned production of vegetables, etc. is made possible through advanced environmental control and growth projections based on the monitoring of the environment and growth. High-tech greenhouses are roughly divided into two categories, i.e., those only utilizing artificial light, where crops are grown without sunlight under a closed environment, and those utilizing sunlight, where sunlight is utilized mainly in greenhouses, etc. with supplementary artificial light and with the help of technology to curb summer heat, etc.^[19] (Figure 7). Controlled environment facilities explained in 4-2 are one type of plant factory that only utilizes sunlight or concurrently utilizes sunlight and artificial light.

High-tech greenhouses have various characteristics, as shown in Table 1, and can be designed flexibly, depending on priorities and combinations of elements and in accordance with use, into such forms as a highly-automated large-scale vegetable plant and a facility for the purpose of creating jobs. However, in any case, high production costs are one of the biggest challenges in diffusing plant factories^[20] (Table 2). Depreciation costs of facilities account for 30 to 40% of the overall production costs, while out of the overall running costs, around 25% is utility costs and 20 to 30% is personnel costs.^[19] These need to be reduced, while considering a balance suitable for the usage of each plant factory. Studies have been conducted in various fields, aiming to commercialize and disseminate high-tech greenhouses, concerning such themes as the development of optimal facility specifications and cultivation systems for specified crop types and the development of fundamental technology for integrated environmental control.^[21]

5-2 Trends in studies relating to the employment of the elderly in controlled environment agriculture

There have been many studies related to the employment of the elderly in controlled environment agriculture, and by combining the results of such studies some effective business models can be described.

5-2-1 Low-cost facilities

If prioritizing job creation in carrying out controlled environment agriculture, the system needs to limit the level of automation and environmental control and leave processes that require manpower. Therefore,

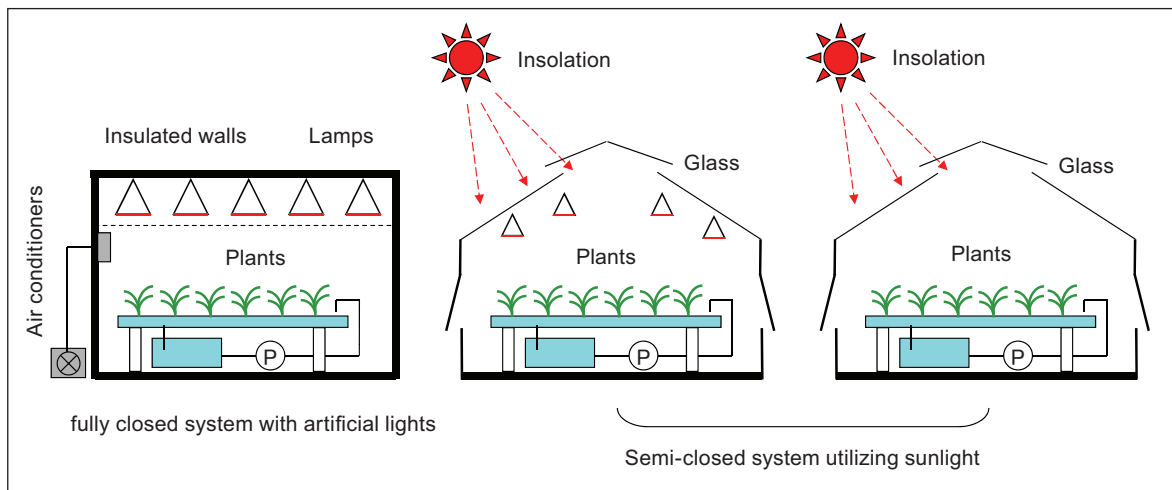


Figure 7 : Classification of High-Tech Greenhouses

Source: With consent of Prof. Eiji Goto (Faculty of Horticulture, Chiba University)

facility construction costs and running costs are mainly required to be reduced.

For example, the Horticulture Institute, Ibaraki Agricultural Center, and two private companies have succeeded in practical applications of a low-cost nutrient solution soil culture system with a capillary water culture system as its basis. The system can be built using various parts that are available from ordinary mass retailers, and attached facilities, such as a large tank for trickle filtering, are simplified. By growing plants in a plastic greenhouse on trial, the companies collected environmental information using a monitoring device and utilized it for cultivation management. This system may also be utilized at plant factories as it discharges little liquid fertilizer waste and works with less electricity.^[22]

5-2-2 Production of high-value-added products

Controlled environment agriculture that prioritizes job creation cannot reduce personnel costs drastically. When it is difficult to maintain business although having sufficiently reduced facility construction costs and running costs, high-value-added products need to be produced. If one can grow expensive or precious crops in cities by fully utilizing the advantageous features of controlled environment agriculture, this will lead to coexistence with conventional agriculture.

At present, most of the medicinal plants are imports from overseas but it has become increasingly difficult to secure their sources due to expanding world demand for crude drugs and excessive harvesting. Recently, an industry-government-academia research group has succeeded in the hydroponic culture of licorice, and the stable production of licorice has

become possible in a plant factory.^[23]

5-2-3 Artificial soil

The hydroponic culture system is suitable for environmental control but types of crops to be grown are mainly limited to leaf vegetables. If stable soil culture is made possible in controlled environment facilities, root vegetables can also be grown and people may be able to enjoy touching and feeling soil in farm work.

Two private companies recently developed artificial soil with a high water and fertilizer retaining capacity by adding original technology to conventional peat moss. This soil facilitates a reduced frequency of watering, requires less water, and does not need top-dressing even when utilized for organic farming. Even with the use of organic fertilizer, the soil contains microbiological agents that are used for preserving food and can suppress the development of bacteria and mold. In the test plant, root vegetables, such as radishes, burdock, and turnips, and fruit vegetables, such as eggplant, okra, and pumpkins, are being grown.^[24]

5-2-4 Development of a working environment for the elderly and the disabled, and verification of validity

Facilities for controlled environment agriculture provide a place for farm work just like citizens' allotment farmlands and rooftop gardens, but they all have different characteristics. It is necessary to verify whether controlled environment agriculture contributes to enhancing the quality of workers' lives by giving them a satisfied feeling.

Table 1 : Characteristics of Plant Factories

Production technology	<ul style="list-style-type: none"> • Comfortable environment in facilities, mainly light work • Growth and quality being adjusted by environmental control • Planned and stable production based on monitoring of the environment and growth and growth projections, instead of only depending on producers' instincts and experience • Enhancement of nutrient components and functional components • Reduction of the use of pesticides, fertilizer, and water
Sales	<ul style="list-style-type: none"> • High yield ratio of products for processing and for professional use, with less food loss • Little contamination with insects or foreign matters, with cost reduction being possible by reducing washing and preparation processes • A stable supply at fixed prices being possible even in cases of typhoons and other weather disasters
Location/Construction	<ul style="list-style-type: none"> • Can be constructed anywhere and enables agricultural production even at places other than farmland or at places not suitable for cultivation • Can be installed even in vacant shops, vacant offices, vacant factories, and vacant warehouses (plant factories only utilizing artificial light) • Highly efficient utilization of spaces by making multitiered plant beds (plant factories only utilizing artificial light)

Source: Reference^[19]

Table 2 : Factors that Increase Production Costs of Plant Factories

Factors	Matters	Details
High facility costs (initial costs)	Dependence on heavily equipped facilities	High dependence on facilities that need to be equipped with environmental control systems and conveying devices in order to maintain year-round high efficiency production
	Inconsistent specifications with little past examples	Standardization of systems being difficult due to differences in factory scales and a limited number of constructions annually
	Heavy burden of depreciation costs	High rate of depreciation cost due to high facility costs
High running costs	High electricity expenses	High dependence on electricity, with electricity expenses constituting a large portion of the overall production costs
	Expensive plant materials	Cultivation containers, etc. with unique specifications being expensive
	Personnel cost	In spite of efforts for laborsaving, such as by introducing conveying devices, many processes require manpower

Source: Reference^[20]

The R&D Center for Plant Factory, Osaka Prefecture University has been working to develop an optimal working environment in plant factories for the elderly and the disabled. With the participation of the School of Comprehensive Rehabilitation of the university, and the Universal Design Group of the Research Institute of Environment, Agriculture and Fisheries, Osaka Prefectural Government, it is scheduled to develop technology to measure the psychological effects that wheelchair workers receive from growing plants and to create horticultural therapy programs.^[25]

5-2-5 Demonstration experiments on models of super-aging societies

Along with R&D of technology for plant factories, demonstration experiments on models of super-aging societies have been conducted. The Research Institute of Science and Technology for Society, Japan Science and Technology Agency, commenced new research on aging societies in FY2010, entitled "Redesigning Communities for Aged Society," which contains four R&D programs. In the program called, "Senior citizens' new career model in the community," a

demonstration experiment has been underway in Kashiwa city, Chiba prefecture, concerning a new society model where the elderly people play roles as supportive members.^[26] Furthermore, a small-scale vegetable factory business is included in the seven business plans under said research.^[27] In the private sector, a social model experiment is planned, aiming to reduce environmental load, cope with the problem of aging, and create jobs, and a vegetable factory is to be operated on trial for the purpose of providing employment opportunities for the elderly.^[28] If a practical business model of a vegetable factory can be verified, this type of business is expected to be diffused in various regions, including urban areas.

5-3 Review of potential as business

When carrying out controlled environment agriculture on a rooftop, air conditioning is indispensable during Japan's hot and humid summer. There are several cooling methods, such as a heat pump cooling system, cold water cooling system, and evaporative cooling system,^[29] but it is necessary to develop an optimal cooling system, while taking into account various factors, including effects, environmental control, and facility costs. Regarding job creation, in the aforementioned case in Montreal, eight to 10 workers are considered to be necessary for nearly 3,000 square-meters of farmland. A survey of eight plant factories concurrently utilizing sunlight and artificial light that are now operating in Japan revealed that there was less than three workers per 1,000 square meters in five facilities and three to five workers in two facilities.^[30] Judging from these data, if a 1,000 square-meter controlled environment facility is constructed on the rooftop of a building, only around two persons can be employed. Therefore, it is necessary to develop a business model and a profitable structure that can ensure certain employment levels.

By using artificial light, crops can be grown indoors without sunlight. Not only rooftops but also other various spaces, such as vacant shops, vacant warehouses, and closed schools, can be utilized, which expands the options for installing facilities. A plant factory only utilizing artificial light in Chichibu city, Saitama prefecture, was constructed using a vacant factory building and the initial costs for starting operation were reduced to around half of those for ordinary facilities.^[31] In the 400 square-meter factory, leaf vegetables are being grown and are directly sold

to hotels and restaurants.^[30] Since its establishment in 2008, the factory has continued business by hiring as many as six workers. This business model may serve as a good example.

6 Conclusion

Controlled environment agriculture is considered to have the potential to provide good employment opportunities for the elderly in urban areas in a super-aging society. Controlled environment agriculture makes it possible to utilize infused resources, such as water and nutrients, efficiently for growing crops. Soil, water, fallen leaves, and other waste does not scatter around, and crops can be cultivated without the use of pesticides. These are all advantages of controlled environment agriculture, which may be developed into a resource-saving type of agriculture suitable for an urban environment, and may promote local production for local consumption, creating a new flow of products and people in cities, as well as help the development of communities especially by encouraging the elderly to get involved by obtaining employment. In the future, we need to picture ideal business models and develop technology to realize them.

In the cases of controlled environment agriculture projects conducted on rooftops in North America, the objective is to create jobs in the relevant regions as a whole, instead of targeting only elderly people. Judging from the results of the survey targeting Tokyo citizens mentioned in 3-1 and the utilization study of rooftop gardens mentioned in 4-1, not only the elderly but other citizens of Tokyo in wider age groups seem to be interested in agriculture and gardening. Therefore, other than the elderly, young people and housewives, who once quit jobs for child rearing, may be included in those seeking jobs in the field of controlled environment agriculture in Japan. If the scope and influence of this type of agriculture expand to all urban residents, its social value will further increase and can be a successful urban model in a super-aging society. It is expected that other foreign countries, such as South Korea, Singapore, and Germany, will become a super-aging society by 2050,^[32] and Japan's urban model adopting controlled environment agriculture may serve as a helpful reference for these countries.

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Profile

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Kazuhito Akasaka has been in his present post since 2010, after having engaged in drug screening, protein expression and purification, as well as research on peptide, etc. at a pharmaceutical company. He is mainly studying research trends concerning overall life science, including medical care, health, and food. He is a Doctor of Medical Science.

(Original Japanese version: published in May 2011)
